APPENDIX B

DESCRIPTIONS OF LIQUID CRYSTAL DISPLAY (LCD) TECHNOLOGY AND AMORPHOUS SILICON THIN-FILM TRANSISTOR (a:Si TFT) TECHNOLOGY

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PRODUCTS

WHAT IS A LIQUID CRYSTAL?

PRINCIPLES OF LCD TECHNOLOGY

LCD PRODUCTION METHODS

AMORPHORUS -Si TFT TECHNOLOGY

PROJECTORS

PANELS AND DIRECT VIEW MONITORS

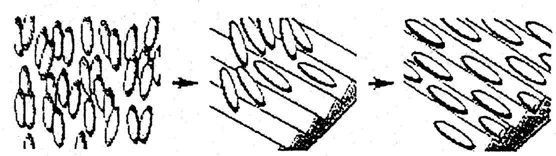
PRO VIDEO PRODUCTS

PRINCIPLES OF LCD TECHNOLOGY

In this section, we will explain everything ranging from the properties of liquid crystal molecules to the basic principle of display technology by using TN type liquid crystals as an example.

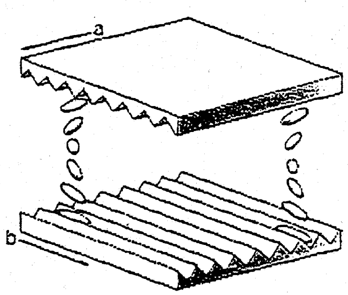
The parallel arrangement of liquid crystal molecules along grooves

When coming into contact with grooved surface in a fixed direction, liquid crystal molecules line up parallel along the grooves.



Natural State Molecules are arranged in a loosely ordered fashion with their long axes parallel.	When coming into contact with a finely grooved surface (alignment layer).	Molecules line up parallel along grooves.

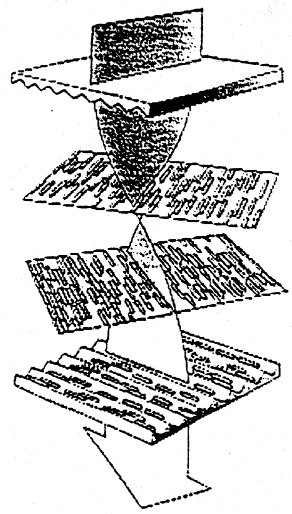
When liquid crystals are sandwiched between upper and lower plates, they line-up with grooves pointing in directions 'a' and 'b,' respectively



The molecules along the upper plate point in direction 'a' and those along the lower plate in direction 'b,' thus forcing the liquid crystals into a twisted structural arrangement.
(figure shows a 90-degree twist)
(TN type liquid crystal)

Light travels through the spacing of the molecular arrangement

The light also "twists" as it passes through the twisted liquid crystals

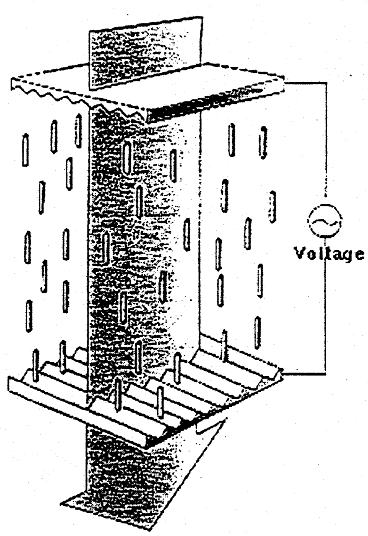


Light passes through liquid crystals, following the direction in which the molecules are arranged. When the molecule arrangement is twisted 90 degrees as shown in the figure, the light also twists 90 degrees as it passes through the liquid crystals.

Light bends 90 degrees as it follows the twist of the molecules

Molecules rearrange themselves when voltage is applied

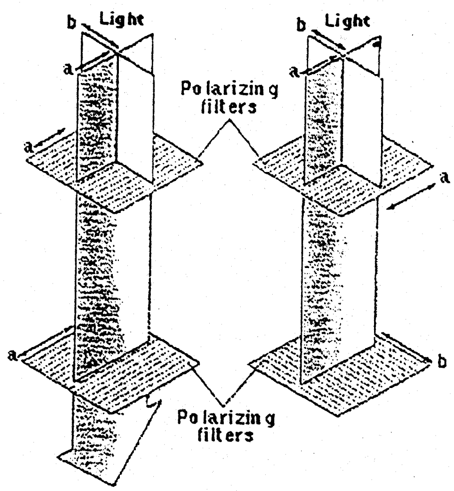
When voltage is applied to the liquid crystal structure, the twisted light passes straight through.



The molecules in liquid crystals are easily rearranged by applying voltage or another external force. When voltage is applied, molecules rearrange themselves vertically (along with the electric field) and light passes straight through along the arrangement of molecules.

Blocking light with two polarizing filters

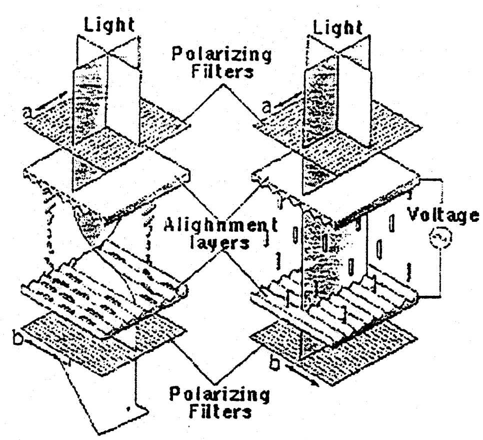
When voltage is applied to a combination of two polarizing filters and twisted liquid crystal, it becomes a LCD display.



Light passes when two polarizing filters are arranged with polarizing axes as shown above, left.
Light is blocked when two polarizing filters are arranged with polarizing axes as shown above, right.

TN type LCDs

A combination of polarizing filters and twisted liquid crystal creates a liquid crystal display.



When two polarizing filters are arranged along perpendicular polarizing axes, light entering from above is re-directed 90 degrees along the helix arrangement of the liquid crystal molecules so that it passes through the lower filter.	When voltage is applied, the liquid crystal molecules straighten out of their helix pattern and stop redirecting the angle of the light, thereby preventing light from passing through the lower filter.

This figure depicts the principle behind typical twisted nematic (TN) liquid crystal displays. In a TN type LCD, liquid crystals in which the molecules form a 90-degree twisted helix, are sandwiched between two polarizing filters. When no voltage is applied, light passes; when voltage is applied, light is blocked and the screen appears black. In other words, the voltage acts as a trigger causing the liquid crystals to function like the shutter of a camera.

PRODUCTS
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LCD PRODUCTION METHODS
AMORPHORUS -SI TFT TECHNOLOGY
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PANELS AND DIRECT VIEW MONITORS
PRO VIDEO PRODUCTS

AMORPHUS-SI TFT TECHNOLOGY

Active matrix LCDs, which are typically used in products such as LCD projectors, are controlled by a switching element known as a thin-film transistor or thin-film diode placed at each pixel.

The fundamental concept was revealed in 1961 by RCA of America, a U.S. company, but basic research only began in the 1970's. Amorphous Si TFT LCDs introduced in 1979 and 1980 have become the mainstream for today's active matrix displays. These units place an active element at each pixel, and taking advantage of the non-linearity of the active element, are able to apply sufficient drive-voltage margin to the liquid crystal itself, even with the increase in the number of scan lines.

As shown in Figure 1, TFT LCDs that use amorphous Si thin-film transistors (TFTs) as the active elements are becoming the mainstream today, and full-color displays achieving contrast ratios of 100:1 and which compare favorably to CRTs are being developed.

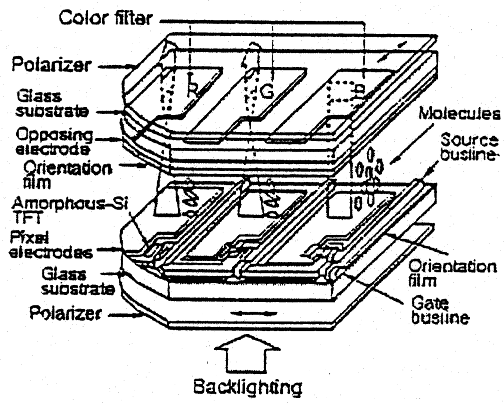

Figure 1 Construction of TFT LCD

The driver electronics for TFT LCDs consist of data-line drive circuitry that applies display signals to the data lines (source drivers) and scanning line drive circuitry that applies scanning signals to the gate lines (gate drivers). A signal control circuit to control these operations and a power supply circuit complete the system.

Liquid crystal materials used in TFT LCDs are TN (twisted nematic) liquid crystals, but despite the fact that pixel counts have increased and a drive element is placed at each pixel, we have still been able to rapidly increase the contrast, viewing angle, and image quality of these displays.

However, manufacturing technologies to fabricate several hundred thousand such elements onto the surface of a large screen are extremely problematic, and the fundamental approach developed in 1987 is still being used today.

In 1988, Sharp developed a 14-inch TFT color TV, and with this development of a futuristic wall-mount TV, TFT LCDs created the foundation for manufacture and introduction of large-screen color displays.

Reinitzer discovered liquid crystals almost 100 years ago, and today, bolstered by customer needs and the new and special technologies and materials that a manufacturer can offer to meet those needs, liquid crystals have made huge strides.

At this opportunity, we would to make the whole world aware of the potential of LCDs, and as new manufacturers enter the market, become the trigger that raises this awareness to new levels.

In the evolution of LCD display manufacturing, the burden of undertaking aggressive development of application products has been considerable. In addition to notebook and sub-notebook PCs that have been the mainstream applications for LCDs in the past, there has been significant growth in areas which take advantage of the unique characteristics of LCD displays, such as compact size, thin profile, and low power consumption to create products which could not be produced using CRTs, such as LCD TVs, ViewCams, new portable information tools, etc. In addition, for large projection TVs, it has now become possible to develop products that are more compact and lighter in weight than conventional CRT-based models, and LCDs are rapidly becoming the mainstream display device in this field.

In this way, LCD displays have expanded into application areas that were once niches belonging solely to CRTs, and the development of numerous key technologies that have the potential to further expand their application product areas continues.

Thanks to the development of TFT LCD displays and the synergistic evolution (spiral evolution) with LCD application devices and equipment, such as PC notebooks and computer monitors, A/V equipment, car navigation systems, game devices, etc., we can anticipate the growth of new demand-generating products. LCDs have emerged as the likely winner among flat-panel displays for the new information-oriented society. As we approach the dawn of the multimedia era which will see the convergence of video, computers, and communications, a critical need is emerging for innovations in displays that link man and machine through our sense of sight.

The driving force behind LCD manufacturing are recently developed amorphous-Si TFT LCD technologies which represent breakthroughs in the areas of 1) higher aperture ratios, 2) wider viewing angles, and 3) EMI (electromagnetic interference) reduction, as well as low-temperature polycrystalline Si TFT LCD display technologies. Thanks to these breakthroughs, a new direction has emerged in 1996 which will make the best use of these key technologies in LCD applications. For example, higher aperture ratio technologies are being used in LCD displays intended for PC notebooks, wider viewing angle and lower EMI technologies are being used in LCDs destined for LCD monitors, and low-temperature polycrystalline Si TFT LCD technologies are being used as super-fine dot-pitch light valves for high-definition projection TV systems.

In the future, promising new technologies can be expected to spawn the next generation of new LCD application products based on high-performance LCD display systems ("systems-on-panel") that takes full advantage of integrated drive and control circuitry.

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References

Sharp. 1998. Information found on a Web page from Sharp USA. Web site available at: <http://www.sharp-usa.com/products/pro/tech/>.